*This chapter is dedicated to my inspiration: my wife, Briane.*

Chapter 1

# Your Muscles: Where They Are and How They Work

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*"The study of exercise would be severely deficient without a basic knowledge of human anatomy and physiology."*

When you were a student, you probably heard this same sort of statement many times and may have seen it applied to every subject that you ever took in school. For example, this statement in a history class might look like this: "The study of the Civil War would be severely deficient without a basic knowledge of the Battle of Gettysburg." Or in an English class: "The study of grammar would be severely deficient without a basic knowledge of sentence structure."

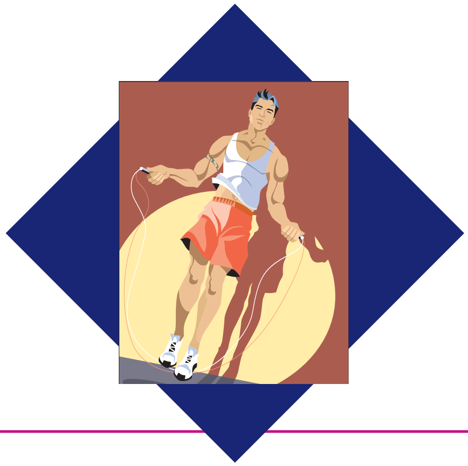
Whatever subject is discussed, it's always prudent to have, at the very least, a fundamental understanding of its basic building blocks. "Why do I need to know those?" is almost always the next question. The answer can be deduced from one very simple example: Try to get from New Jersey to Southern California without the use of any kind of map, compass or computer. Given enough time, most Garden Staters could manage to accomplish this task. But wouldn't it be a lot easier to do if you had the exact directions?

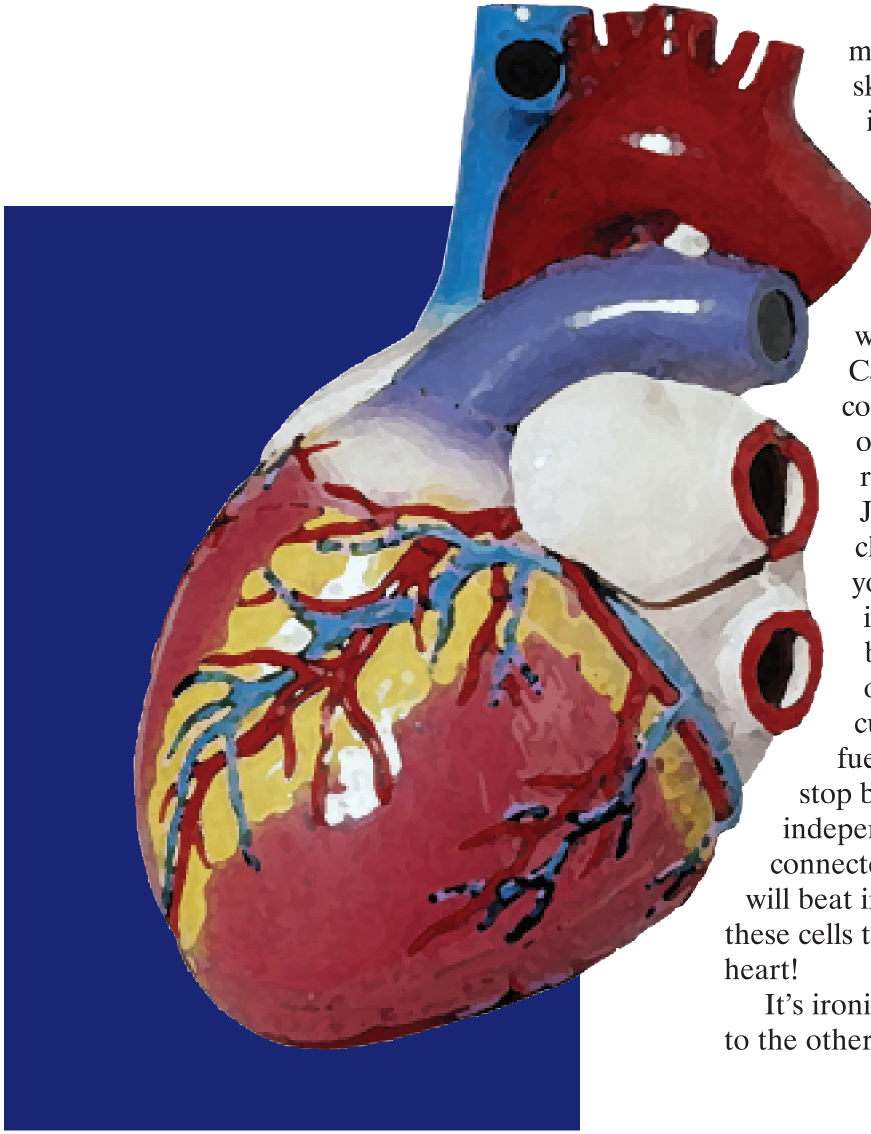
The purpose of this chapter, therefore, is simplicity. There are more than 600 muscles in your body and to try to study them all would be futile in the context that you'd need to understand them. When it comes to physical training, for instance, muscles used for chewing are less significant than muscles used for running. By the end of this chapter, you should be able to answer the following questions:

- **Are all muscles the same?**
- **How are the muscles of a sprinter different than the muscles of a distance runner?**
- **How do muscles interact with one another?**
- **What are the major muscles of the body and what are their respective functions?**
- **What are some physiological adaptations to strength training and aerobic training?**

## MUSCLE TYPES

A discussion of basic anatomy and muscular function cannot proceed without a description of the actual muscle types that comprise the human body. In general, humans are composed of three types of





muscle: cardiac, smooth and skeletal. Each type of muscle has its own distinct characteristics and, thus, is unique.

## Cardiac Muscle

As the name would suggest, cardiac muscle is the type of which the heart is composed. Cardiac muscle is unique in that it conducts electrical impulses like any other muscle but its cells “beat” rhythmically to these impulses. Just as your heart beats in your chest to push blood throughout your body, these cells – when isolated from one another – will beat independently from any outside source of electrical current. Only when their cellular fuel source runs out will these cells stop beating. When several of these independently beating cells are connected to one another, all of the cells will beat in unison. Put a few million of these cells together and you have the human heart!

It’s ironic that when the heart is compared to the other muscles in the body, its size ranks near the bottom. The importance of the heart, however, cannot be overestimated, as it’s the single most important muscle that you have. (The physical and physiological adaptations that the heart makes in response to exercise will be discussed shortly.)

## Smooth Muscle

The organs of your body – such as the esophagus, stomach and small intestine – are composed mainly of smooth muscle. It’s given the name “smooth” due to its smooth, nondescript texture. The primary purpose of smooth muscle is simple: it works without you knowing that it’s working.

If you had to constantly and consciously control the actions of your stomach, esophagus and other various organs, you’d be too overwhelmed to do anything else. Smooth muscle is designed to be active 24 hours a day, seven days a week without an ounce of conscious effort on your part. It’s for these reasons that smooth muscle is sometimes referred to as “involuntary” muscle.

### Skeletal Muscle

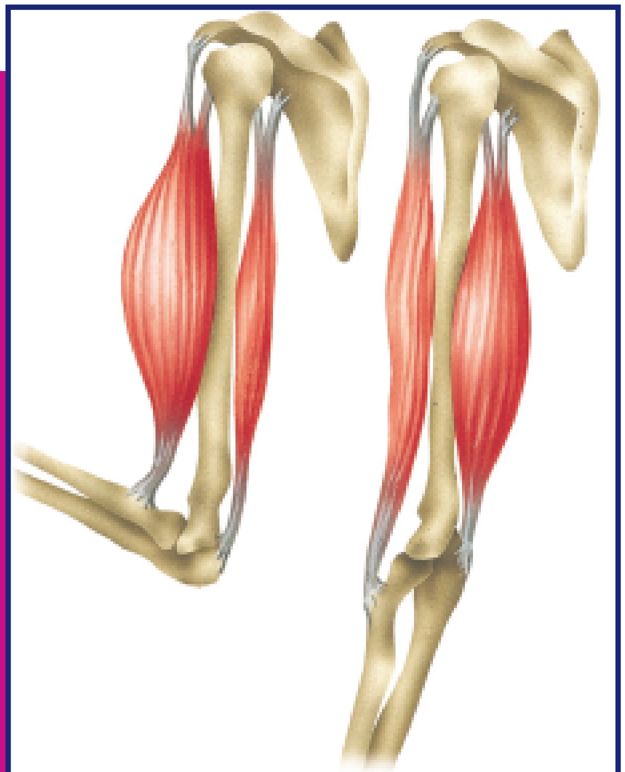
As the name implies, skeletal muscles are directly responsible for the physical movement of the skeleton. Unlike its cardiac and smooth counterparts – which tend to be suspended in the body cavities by other tissues – all skeletal muscle, at some point or another, is directly attached to the skeleton. Also, skeletal muscle is voluntarily controlled which means that a conscious effort is required in order to contract the muscle and cause movement. Another unique characteristic of skeletal muscle is that it has a grooved or “striated” appearance due to the orientation of the muscle fibers. Because of this phenomenon, you’ll sometimes hear it referred to as either “striated muscle” or “striated skeletal muscle.”

Within striated muscle, there exists a subset of fiber types with which you may be more familiar than you know.

## MUSCLE-FIBER TYPES

Elite sprinters and distance runners are superior athletes who are capable of astonishing feats on a track. Sprinters tend to be lean and have better than average musculature, especially in their hips and thighs; distance runners, while just as lean, tend to carry much less muscle even though they run greater distances. Sprinters are capable of generating an enormous amount of speed and power whereas distance runners generate much less speed and power. Another major difference between the two is that distance runners can continue their efforts for a much greater period of time than can a sprinter. So, then, are there differences between these two athletes in the way that they train or does it have something to do with their anatomical makeup?

If sprinters were to suddenly alter their training routines to include much longer runs, could they become champion distance runners? The possibility exists but it’s highly unlikely because sprinters are limited by their genetic (or inherited) characteristics. These genetics control what fuel source that the muscles in the body – in this case, the lower body – utilize for energy. No doubt, a successful sprinter’s hips and legs would have a higher percentage of what are known as “Type II” or “fast-twitch” muscle fibers. These fibers are large, white in appearance and primarily fueled by the metabolism of sugar. The white appearance of fast-twitch muscle is largely due to the structural



makeup of the fibers. Their structure allows for a minimal amount of blood flow to the actual muscle fiber. Combine the low blood flow and the rapidity with which the body utilizes sugar for energy and it's easy to see why these muscle fibers fatigue rather quickly.

On the other hand, successful distance runners would likely have a generous supply of what are known as "Type I" or "slow-twitch" muscle fibers. These fibers are smaller than Type II fibers and are red in appearance due to the greater degree of blood flow that they receive. The metabolism of a longer functioning fuel source – fats in this case – allows these muscles to sustain their metabolic and physical activity for a much greater length of time.

Does this mean that an individual's muscles are either all fast-twitch or all slow-twitch fibers? Obviously not, otherwise a person would be either an outstanding sprinter or distance runner. The majority of the population has a relatively even mix of both of these fibers as well as some of a third type of fiber: Type IIa. These would be the "middle-of-the-road" fibers that have characteristics of both Type I and II fibers.

This muscle-fiber phenomenon does give some credence to the idea that champion athletes are born and not made. Take two athletes of the same size, relative strength and training experience. Let's call them "Rabbit" and "Turtle." Rabbit is born with a higher percentage of fast-twitch fibers while "Turtle" is born with a higher percentage of slow-twitch fibers. Turtle begins a rigorous training regimen of sprints, leg-strengthening exercises and form running and continues this for many months. But no matter how much Turtle sprints, strengthens his legs and practices his form, Rabbit will always have a distinct advantage over Turtle in short-term, high-intensity efforts. Now, Turtle may get faster by maximizing the fast-twitch fibers that he has but will never be able to overcome the genetic advantage that Rabbit has. In short, Rabbit wouldn't have to train nearly as hard as Turtle in order to be faster.

## SKELETAL MUSCLE INTERACTION

Whether you've done strength training or read about the programs of others, you've probably come across the concept of push/pull workouts. This notion revolves around the idea that some muscles "push" a weight away from you whereas other (or opposite) muscles "pull" a weight toward you. While muscles may physically move something away from you or toward you, they're just not physically designed to push anything. In actuality, muscles simply shorten or contract upon themselves. This fact has been well documented with the acceptance of the Sliding Filament Theory of muscle contraction.

The basis of the theory goes something like this: Muscle is composed of tens of thousands of fibers arranged in bundles. These bundles of muscle fibers are what actually cause muscle contraction and, ultimately, movement of the skeleton. How do they accomplish this feat? Within these muscle fibers is the basic unit of muscle contraction: the sarcomere. (See Figure 1.1.) Sarcomeres are composed of thick protein filaments called "myosin" and thin protein filaments called "actin." The thinner actin filaments surround, on either side, the thicker myosin. When the muscle cells receive a contractile message from the Central Nervous System, little arms (called "globular myosin heads") reach out from the myosin and pull the actin filaments on either side toward the middle of the sarcomere. The filaments slide much like pistons in a sleeve, thus the name "Sliding Filament Theory."

### Functional Groups of Muscles

Essentially, your muscles can be considered to belong to any of four functional groups: *prime movers, antagonists, synergists and fixators.* These four groups are detailed in the upcoming section.

### Prime movers

If muscle "A" is the primary muscle being utilized in a certain exercise – that is, it's the muscle actively contracting – then that muscle is called a "prime mover" or an "agonist." So during a bench press, the pectoralis major on the front of the torso would be considered a prime mover.

### Antagonists

During an exercise, some muscles provide stability and structural support to the movement by acting in the opposite direction (or lengthening). These muscles are called

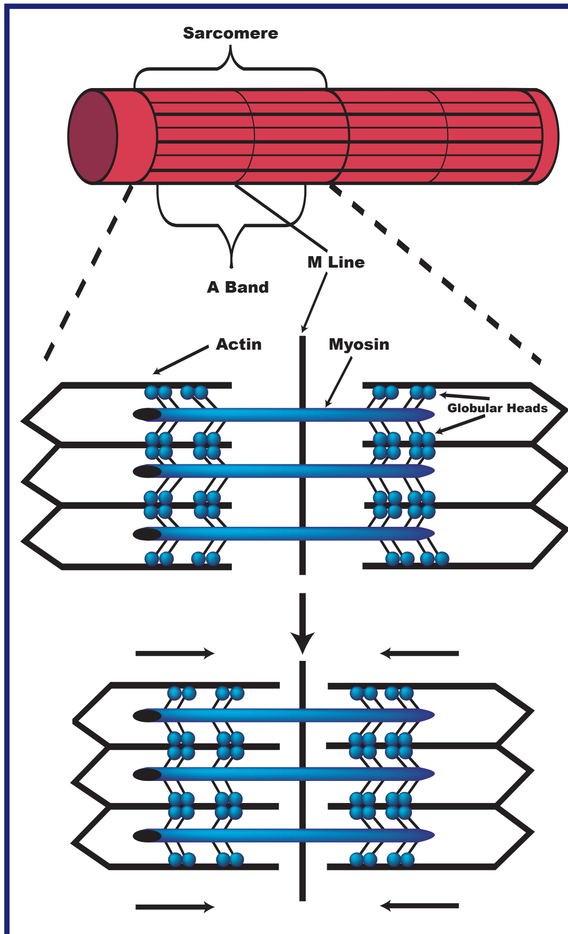
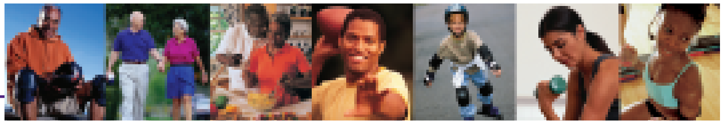



Figure 1.1- **The Sarcomere. In any typical muscle fiber, sarcomeres are lined up end-to-end, thousands of sarcomeres long. The more sarcomeres situated next to each other in a row, the more force a muscle can generate.**



"antagonists." In the case of the bench press, the muscles of your upper back – mainly the latissimus dorsi – would be the antagonists.

Perhaps an even better example would be the muscles that are involved with any throwing motion. The primary extender of the forearm is the triceps on the back of your upper arm. If this muscle was allowed to contract fully without any kind of counteraction, it would most certainly hyperextend your elbow and cause damage to the nerves, tendons and ligaments in and around the joint. Here, the antagonistic muscle would need to be the biceps on the front of your upper arm. While the arm is extending, the biceps lengthen but only up to the point where damage could occur at the elbow joint. At this point, the biceps would begin to contract in order to halt the momentum of the extension of the lower arm.

## Synergists

Let's take a look at the bench press again and examine this motion more closely because there are other muscles that help the pectoralis major (the chest) during this exercise. Muscles such as your triceps and deltoids assist the pectoralis major in moving the bar away from your body. Since these muscles work together, they're called "synergists." Another common example would be the muscles of your forearms working together to form a fist. Wrap your open palm around the thickest part of your opposite forearm (nearest your elbow) and open and close your hand. It's easy to feel almost the entire musculature contract and relax at the same time.

## Fixators

The last functional group of muscles is the "fixators." These muscles tend to be "tensed" during a movement but don't actively contribute to the activity that's being performed. During a squatting movement, for example, most people tend to hold their breath and tense their abdominal muscles. The muscles that are actively moving your body up and down are your hips and legs but the "fixators" help to support your torso.

## MAJOR MUSCLES

It's well beyond the scope of this chapter to discuss the major muscles of your body in great detail. However, a summary of those muscles is shown in Figures 1.2 and 1.3 (pages 7 and 9). In addition, the anterior (front) and posterior (back) views of the body are shown in Appendices A and B (page 217).

## ADAPTATIONS TO EXERCISE

The physical and physiological adaptations to exercise can be divided into two different categories based on whether the activity is aerobic or anaerobic in nature.

Strength training is a form of anaerobic exercise that typically results in someone getting "bigger and stronger." But can someone get stronger without getting bigger? The answer to this question is "yes" because of the different physiological adaptations that take place.

Let's use strength improvement in the barbell bench press as an example. Someone who attempts to do this exercise for the first time may be more than capable of lifting 135 pounds but their movement will be strained and almost clumsy in appearance? Why? The answer is simple: The body hasn't

### Figure 1.2 - Major Muscles of the Hips, Legs and Mid-Section

| MUSCLE GROUP | MUSCLE NAME | LOCATION | FUNCTION |
|---|---|---|---|
| **Hips** | gluteus maximus | posterior and superficial; forms bulk of buttocks | hip extension; allows thigh to align with pelvis and spine; powerful muscle |
| | gluteus medius | posterior; internal to gluteus maximus; runs from hip bone to femur | hip abduction; provides pelvic support during running/walking; preferred site for intramuscular injections |
| **Pelvis/Hip** | iliopsoas | anterior; runs from hip/spine to femur; composed of two fused muscles | hip flexion |
| **Upper Leg** | hamstring (group) | forms bulk of posterior upper leg; composed of three muscles: biceps femoris, semitendinosus and semimembranosus | leg flexion |
| | quadricep (group)<br>adductor (group) | forms bulk of anterior upper leg; composed of four muscles: rectus femoris, vastus lateralis, vastus intermedius and vastus medialis | leg extension |
| | | medial or inner thigh | hip adduction (pulls legs together) |
| **Lower Leg** | calves | posterior portion of lower leg; composed mainly of two muscles: gastrocnemius and soleus | plantar flexion of foot |
| | calcaneal | posterior lower leg | not a muscle but rather, the Achilles tendon; connects gastrocnemius to heel |
| | tibialis anterior | anterior; superficial | dorsi flexion and inversion of foot |
| | extensor digitorum longus | | |
| **Abdomen** | rectus abdominis | lateral to tibialis anterior | toe extension; dorsi flexion of foot |
| | external oblique | anterior, paired and superficial (either side of mid-line); gives the "washboard" appearance | flexes spine; assists in forced breathing, childbirth and defecation |
| **Lower Back** | internal oblique<br>transversus abdominis | anterior, paired and superficial; from last eight ribs to the ilium bone | flexes spine; rotation and lateral bending of the torso |
| | erector spinae | anterior, paired, internal to external oblique; from iliac crest to the last three ribs | flexes spine; rotation and lateral bending of the torso |
| | | anterior and deepest of abdominal muscles | compresses contents of abdomen |
| | | posterior; lateral to either side of spinal column; composed of three muscle columns; runs entire length of spine | extends backward; provides stability when bending forward |

acquired that specific skill yet. Think of a child riding a bicycle for the first time. The child will wobble back and forth and seemingly use every muscle in his or her upper and lower body to get the bicycle moving and keep it balanced. Gradually, as the result of more and more practicing, the body will minimize any non-essential muscle involvement so as to make itself more efficient at performing the activity. Returning to the barbell bench press, consider the same person after performing (practicing) the same activity over and over again. The movement is much more "streamlined" and efficient now than it was when it was first tried. This may give the appearance that it was because the person became stronger in the activity when in fact it was because the person merely became better at doing the activity.

The second thing that'll happen to the person performing the barbell bench press will be a "resetting" of the nervous system that allows more weight to be moved then before. As was previously stated, the person may be more than strong enough to lift 135 pounds but not skilled enough to perform the exercise. Now that this person is skilled at the exercise, the body will adjust its "safety mechanism" and enable the individual to lift a weight closer to the maximal load that the involved muscles can handle. What's the safety mechanism? Simply, muscles require neural impulses in order to contract. The stronger and more frequent the neural impulses, the more muscle can be activated and ultimately contracted. If you've never done an exercise such as a barbell bench press, your body will not send impulses as strong – or as many – to the muscles involved until it's evident that the muscles are able to handle the workload.

Lastly, muscles will get larger and denser as a result of strength training (much more noticeably in a man than a woman). The density comes from more cross-bridge attachments forming between the muscle fibers. When more cross-bridge attachments form, they create more intramuscular friction which, in turn, makes the muscle stronger. The increase in size is a result of more intracellular fluid in the actual muscle cells.

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This increase in fluid results from the now stronger and denser muscle, requiring more nutrients.

Other important adaptations that can occur as a result of strength training are:

- **an increased ability to create and tolerate lactic acid**
- **an increase in the amount of enzymes in the body that break down glucose (the preferred fuel source for muscular contraction)**
- **an increase in the resting levels of glucose and other molecules that aid in muscular contraction**

Along with the incredible benefits of strength training, there are numerous positive physiological adaptations that take place when an individual undergoes an aerobic-training regimen. Some, but certainly not all, of the benefits are:

- **an increased cellular production of larger and more numerous mitochondria to supply energy to the cells**
- **a greater ability to create muscle-contracting molecules like adenosine triphosphate (ATP)**

Figure 1.3 - Major Muscles of the Torso

| MUSCLE GROUP | MUSCLE NAME | LOCATION | FUNCTION |
|---|---|---|---|
| Neck | sternocleidomastoid | anterior; both sides of neck; runs from sternum to clavicle | flexes neck; brings head forward |
| | trapezius | posterior; runs from base of skull to thoracic vertebrae vertically, lateral to clavicle and scapula | extends head backward; elevates (shrugs), adducts and stabilizes scapula |
| Chest | pectoralis major | anterior; fan-shaped muscle that covers upper part of chest | adducts arm across torso |
| | intercostals | between rib bones | assists in breathing (both inhaling and exhaling) |
| Shoulders | deltoid (three heads) | lateral, paired; runs from clavicle (anterior) to scapula (posterior) | adducts arm away from body |
| | rotator cuff | internal to deltoid; composed of four "pinky"-sized muscles: supraspinatus, infraspinatus, teres minor, subscapularis | external and internal rotation of arm; critical to holding shoulder in socket joint |
| Upper Back | latissimus dorsi | posterior and paired; large, flat muscle; runs from ilium to lower spine to upper arm | draws upper arm backward and toward torso |
| Upper Arm | triceps brachii | posterior of upper arms; group of three muscles; runs from shoulder girdle to elbow joint | extends lower arm (elbow extension) elbow flexor |
| | brachialis | internal to biceps brachii | flexes lower arm (elbow flexion); supinates forearm |
| | biceps brachii | anterior of upper arms; runs from shoulder girdle to radius bone | |
| Forearm | brachioradialis | lateral portion of forearms | weak elbow flexor |
| | flexors (group) | anterior portion of forearm; numerous muscles in this group | flexes fingers and wrist |
| | extensors (group) | posterior portion of forearm; numerous muscles in this group | extends fingers and wrist |

Strength training is a form of anaerobic exercise that typically results in someone getting "bigger and stronger." But can someone get stronger without getting bigger? The answer to this question is "yes" because of the different physiological adaptations that take place.

- **a greater ability to utilize fats for energy**
- **an increase in the weight and volume of the heart (meaning that more blood can be pumped per beat)**
- **an increased plasma volume to supply more nutrients to the muscles**
- **a decrease in resting heart rate**
- **an increase in stroke volume and cardiac output (meaning that more work can be done with less effort)**
- **an increase in the oxygen extracted from the blood**
- **an increase in total muscle blood flow**
- **a decrease in blood pressure**

## THE LAST LEG

Be it strength or aerobic training, the bottom line of any exercise plan is simple: Exercise for fun, injury prevention and a long, healthy life!